Appendix B

Bridge Investment Analysis Methodology

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The National Bridge Investment Analysis System (NBIAS), first introduced in the 1999 edition of the C&P report, models investments in bridge repair and rehabilitation and functional improvements. This appendix contains a technical description of the methods used in NBIAS to predict future nationwide bridge conditions and analyze bridge investment, including information on the system overview, determination of functional needs, determination of repair and rehabilitation needs, and planned improvements to future versions of the system.

The NBIAS incorporates analytical methods from the Pontis Bridge Management System (Pontis). Pontis was first developed by the Federal Highway Administration (FHWA) in 1989 and is now owned by the American Association of State Highway and Transportation Officials, which licenses the system to over 50 State transportation departments and other agencies. The NBIAS is designed to work directly with data from the National Bridge Inventory (NBI) if the more detailed element-level data required by Pontis are not available. The NBIAS also includes some economic analysis features that are not currently included in Pontis.

NBIAS Overview

The NBIAS is an investment analysis tool used to analyze bridge repair, rehabilitation, and functional improvement investment needs. The system can be used to examine the backlog of needs, in dollars and number of bridges; distribution of work done, in dollars and number of bridges; aggregate and user benefits; benefit-cost ratios for work performed; and physical measures of bridge conditions. Outcomes can be presented by type of work, functional classification, whether the bridges are part of the National Highway System, and/or whether the bridges are part of the Strategic Highway Network.

The NBIAS begins with the NBI database. To estimate functional improvement needs, NBIAS applies a set of improvement standards and costs that can be modified by the system user to each bridge in the NBI. The system uses the available NBI data to predict detailed structural element data for each bridge. The system then measures repair and rehabilitation needs at the bridge element level using a Markov modeling, optimization, and simulation approach and default models derived from Pontis.

The NBIAS is composed of two distinct modules. The Analytical Module allows the users to create an NBIAS database from NBI files, specify technical parameters, and define and run budget scenarios for analysis. The "What-If" Analysis Module provides a variety of interactive screens and reports that display the outcomes for a selected scenario.

The following paragraphs provide additional detail on components of the system that differ from the basic analysis approach in Pontis and/or that have been modified since the 2004 C&P Report.

Determining Functional Improvement Needs

The NBIAS determines needs for the following types of bridge functional improvements: widening existing bridge lanes, raising bridges to increase vertical clearances, and strengthening bridges to increase load-carrying capacity. Functional improvement needs are determined by applying user-specified standards to the

existing bridge inventory, subject to benefit-cost considerations. For instance, a need to raise a bridge will be identified if the vertical clearance under the bridge fails to meet the specified standard and if the increased cost of diverting commercial vehicles around the bridge exceeds the cost of improving the bridge.

Relative to the version of NBIAS used for the 2004 C&P report, the version used for this report considers a broader set of standards in determining whether there is potential need for a functional improvement to a bridge. Functional issues that may result in a deduction in the Sufficiency Rating or in a bridge being classified as structurally deficient or functionally obsolete now are considered in the calculations. Specifically, additional standards are now applied for evaluating bridge width and load ratings that are based on the amount of traffic on and the functional classification of the bridge, consistent with the calculation approach used for NBI Item 67 (Structural Evaluation) and NBI Item 68 (Deck Geometry), and for calculating the Sufficiency Rating. Further, additional standards are now being applied for evaluating vertical clearance and underclearances based on the functional classification of the affected roadways, consistent with the calculation approach used for NBI Item 69 (Underclearances, Vertical and Horizontal), and for calculating the Sufficiency Rating. Potential improvement needs identified using these standards are subject to benefit-cost considerations, as are potential needs identified using user-specified standards described above.

Because the benefit predicted for a functional improvement increases proportionately with the amount of traffic, the determination of whether a functional improvement is justified and the amount of benefit from the improvement is heavily dependent upon predicted traffic. In the current version of NBIAS, traffic predictions are made for each year in an analysis period based on NBI data. The NBIAS allows the user to apply either linear or exponential traffic growth projections. Linear growth was selected for this edition of the report to be consistent with the assumption used in the Highway Economic Requirements System (HERS), as discussed in Chapter 9. This approach assumes that the rate of traffic growth will decline over the course of the period being analyzed and is intended to provide more accurate estimates of benefits from functional improvements.

In evaluating functional improvement needs (as well as repair and rehabilitation needs discussed in the next section), the system uses a set of unit costs of different improvement and preservation actions. These costs, based on Pontis defaults, are scaled based on comparison of the default bridge replacement cost in Pontis to a nationwide average value determined based on analysis of the available NBI data.

Determining Repair and Rehabilitation Needs

To determine repair and rehabilitation needs, NBIAS predicts what elements exist on each bridge in the U.S. bridge inventory and applies a set of deterioration and cost models to the existing bridge inventory to determine the optimal preservation actions to take to maintain the bridge inventory in a state of good repair while minimizing user and agency costs. The following paragraphs discuss major aspects of the repair and rehabilitation modeling approach.

Predicting Bridge Element Composition

Because the NBIAS analytical approach relies on use of structural element data not available in the NBI, NBIAS uses a set of Synthesis, Quantity, and Condition (SQC) models to predict what elements exist on each bridge in the NBI and the condition of those elements. Consistent with the version of the system used for the 2004 C&P report, the current version of NBIAS estimates repair and rehabilitation needs at the element level for each bridge in the NBI. These NBIAS procedures are unchanged from the 2004 C&P report, and were developed through analysis of NBI and element-level data for a sample database of over 10,000 bridges, including representative sample data from bridges across the United States.

The current version of NBIAS has the capability to accept the direct import of structural element data where these data are available, but this capability was not used for the development of this report. While most of the States now routinely collect such data as part of the bridge inspection process, these data are not currently part of the NBI data set. It is expected that in the future structural element data may be provided by some or all States. Once a mechanism is established for sharing these data, they could be incorporated in future NBIAS analyses to improve the prediction of bridge element composition.

Calculating Deterioration Rates

The NBIAS uses a probabilistic approach to modeling bridge deterioration based on techniques first developed for Pontis. In the system, deterioration rates are specified for each bridge element through a set of transition probabilities that specify the likelihood of transition from one condition state to another over time. The current version of NBIAS uses the same set of deterioration models as the version used for the 2004 C&P report. That version of the system used a set of models recalibrated using the historical NBI data for the years 1992 to 2002, resulting in a significant revision of the transition probability matrices relative to models used prior to the 2004 C&P report.

Applying the Preservation Policy

Using transition probability data, together with information on preservation action costs and user costs for operating on deteriorated bridge decks, NBIAS applies the Markov modeling approach from Pontis to determine the optimal set of repair and rehabilitation actions to take for each bridge element based on the condition of the element. During the simulation process, the preservation policy is applied to each bridge in the NBI to determine bridge preservation work needed to minimize user and agency costs over time.

Because the current version of the system models maintenance, repair, and rehabilitation needs for each bridge, the cost of performing preservation work can be compared with the cost of completely replacing a bridge. The NBIAS may determine replacement of a bridge is needed if replacement is the most cost-effective means to satisfy the existing needs. Alternatively, if the physical condition of the bridge has deteriorated to a point where the bridge is considered unsafe (where the threshold for such a determination is specified by the system user), the system may consider bridge replacement to be the only feasible alternative for the bridge. The application of the preservation policy at the bridge level, and consideration of the trade-off between performing bridge rehabilitation or replacement, was a new feature of the system in the version used for the 2004 C&P report, but no further changes have been made in the version used for this report.

Expert Peer Review Panel

Peer reviews by panels of outside experts are an effective way to ensure that the methodologies and analytical tools used in the C&P report continue to meet acceptable standards of technical merit. Under the Office of Management and Budget's *Final Information Quality Bulletin for Peer Review,* such reviews are also required for any "highly influential scientific disseminations," a category that has been deemed to include the C&P analytical tools used for the highway and bridge investment analysis, HERS and NBIAS.

While the HERS model received extensive scrutiny from various external technical panels in its early development, previous reviews of NBIAS had been conducted mainly within the Department. The FHWA recently hired a contractor to assemble three expert panels, two of which charged with reviewing different aspects of the HERS model (see Appendix A). The remaining six-person panel was charged with conducting a more comprehensive review of NBIAS. The final reports from each of the panels are available at http://www.dot.gov/peerrt.htm.

The NBIAS technical review panel included a mix of State practitioners and university researchers, with different areas of relevant expertise including bridge engineering, bridge management, economics, and asset management. The panel reviewed the online and written documentation for NBIAS and found it to be lacking in a number of key areas. It concurred that future reviews of NBIAS could be conducted more effectively if the documentation of the model were improved. The panel identified some aspects of NBIAS that could be useful to States in support of their long-range planning efforts, but that any such application would require improved documentation of the model's procedures.

The panel noted the limitations implicit in the least-cost approach used in NBIAS to select maintenance, repair, and rehabilitation (MR&R) strategies. This approach effectively optimizes its recommended plan of future investments assuming that funding will be available to implement it, which may or may not be the case depending on the scenario being analyzed. This creates the potential that the solution identified by the model may be suboptimal in cases where available funding is constrained, and could cause the model recommendations to deviate further from typical State bridge management practices.

The panel noted the NBIAS's current inability to account for the effects of scour on bridges. An ongoing National Cooperative Highway Research Program (NCHRP) research project was identified that could be used as a possible source of data for developing such procedures in the future for Pontis and NBIAS. One reviewer noted that NBIAS's current simplistic method of computing bridge deck area by multiplying the bridge length and width as coded in the NBI would underestimate the investment scenarios for bridges with varying deck widths and other complex geometrics. It was noted that improvements to this procedure would require additional data to be collected.

The panel recommended that additional calibration of NBIAS should be conducted beyond the data from 11 States originally used to compute values for the various model parameters. It suggested that such calibration should be conducted with an emphasis on obtaining data from all climate zones in the Nation and covering all construction cost areas, to allow the model to reflect the different costs and bridge deterioration rates that exist in different parts of the country.

The panel also questioned FHWA's screening out of culverts from the database, indicating that this resulted in the exclusion of a significant portion of the costs and work associated with maintaining the highway system. (This procedure was originally implemented in NBIAS by FHWA due to concerns that including these investments would double-count those already picked up by the HERS model; further research would be required to determine whether or not this problem still exists).